

g-LIMIT Controls Analysis for PR4

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Agenda

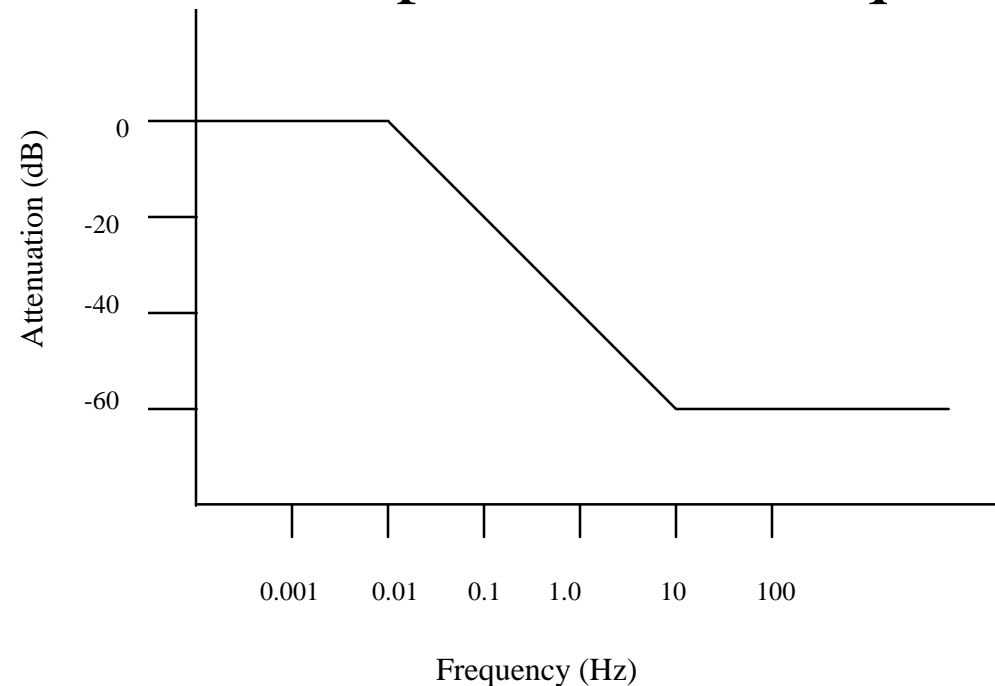
- g-LIMIT configuration and assumptions
- Driving design requirements
- Design approach
- 1-DOF design, stability and performance analysis
 - Translational acceleration control
 - Translational position control
 - Rotational position control
- 6-DOF stability and performance analysis
- Conclusions

g-LIMIT Configuration & Assumptions

- Platform/payload combination modeled as a rigid mass
- Umbilical modeled as a linear spring/damper system
- Disturbance accelerations (that we want to attenuate at the Platform) are modeled as acceleration inputs applied at the base and propagated through the umbilical
- Model data is from the Mass Properties Report #2 dated Jan. 24th, 2000
- Mass and inertia data from Table III (page 24) with the “Flotor with DCP” configuration
- Umbilical Stiffness assumed to 50 N/m with 5% damping

Design Requirements

- g-LIMIT attenuation performance requirement



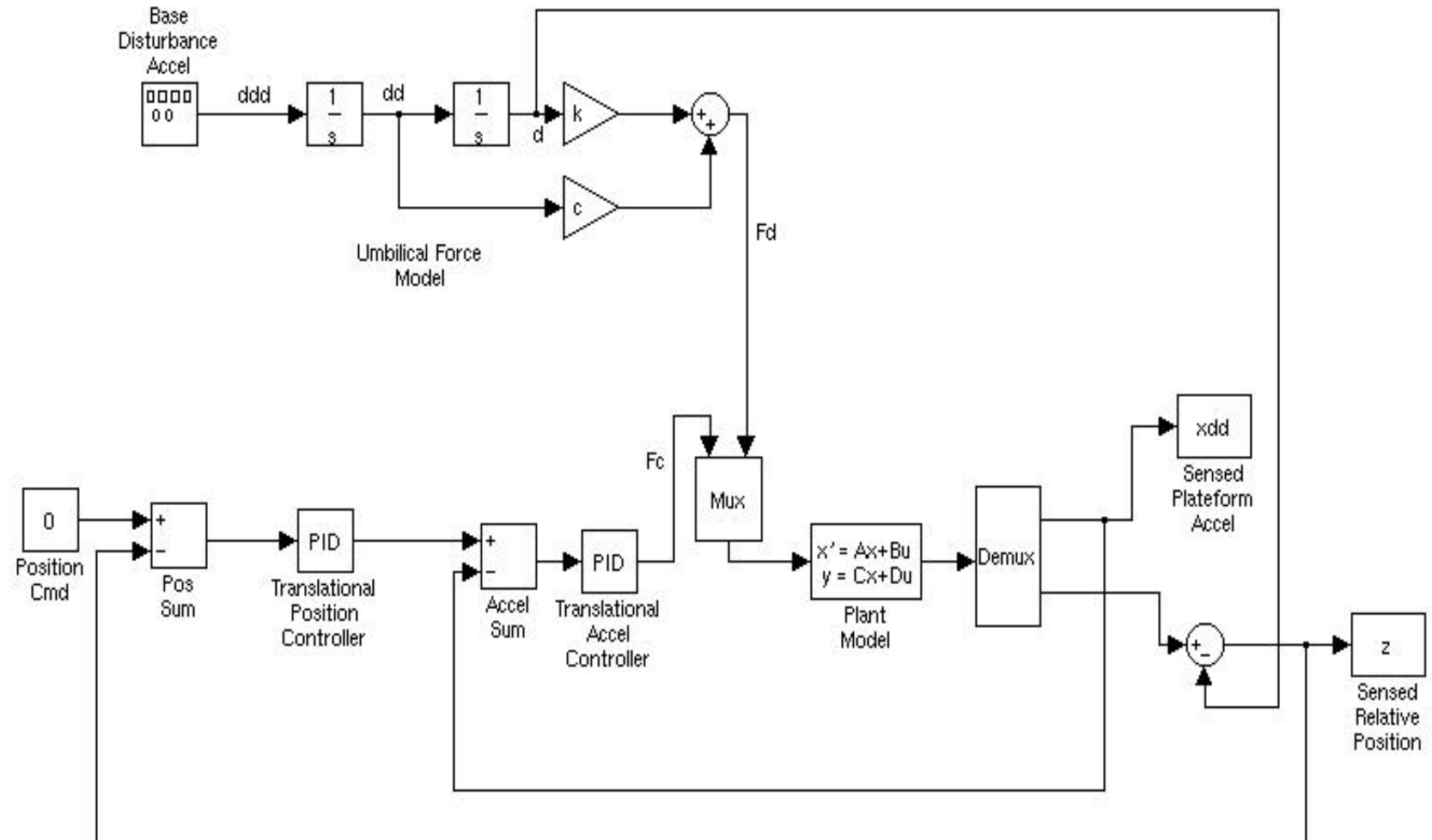
- Maintain platform close to the center of the rattle space

Design Approach

- Controls designed for the 1-DOF system
 - Incorporate excess stability margin
 - Evaluate performance
- Implement 1-DOF controls design on 6-DOF system
 - Evaluate stability and performance
 - Modify design where appropriate
- Design and analysis performed in the continuous domain

1-DOF Design, Stability and Performance Analysis

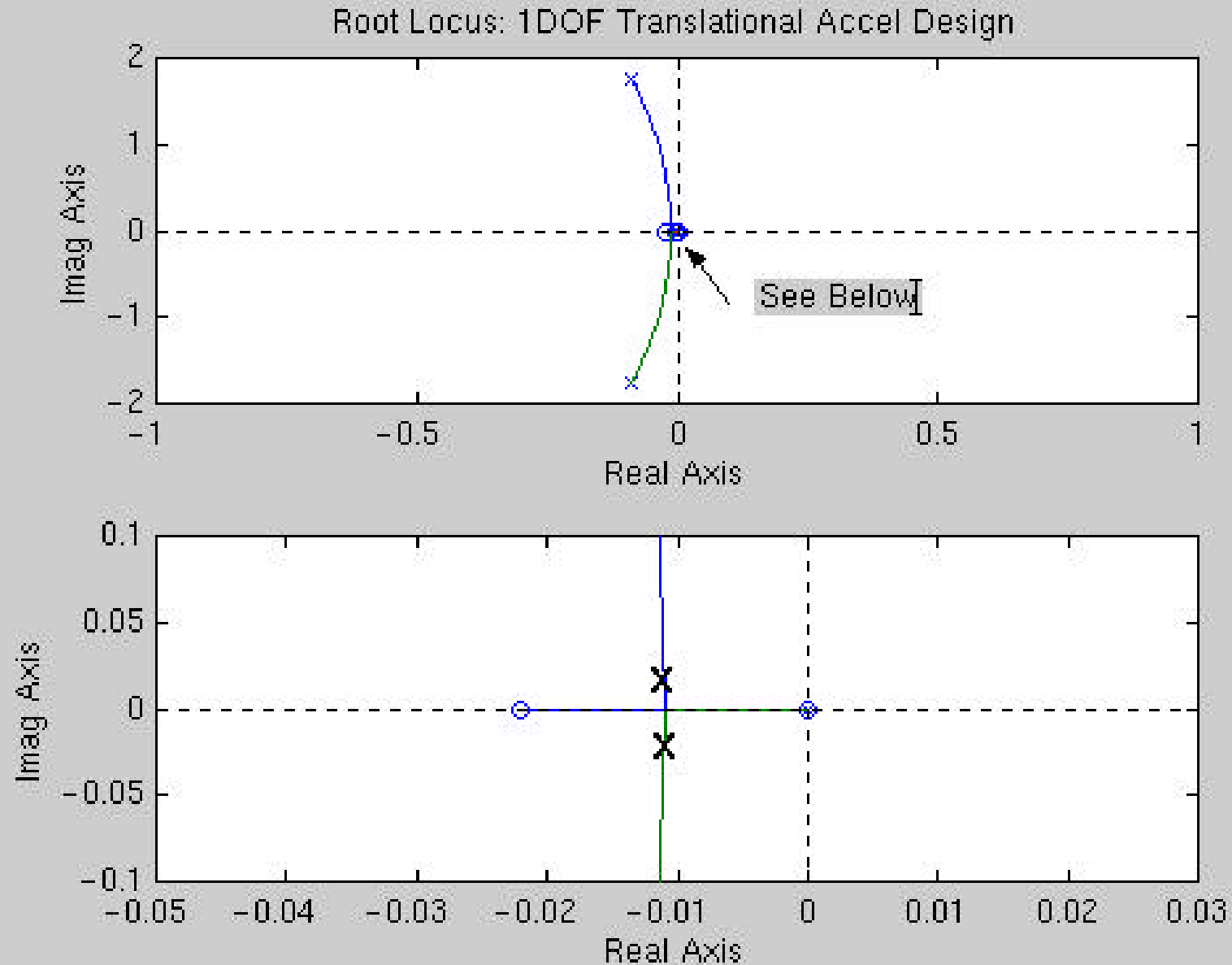
1-DOF Model



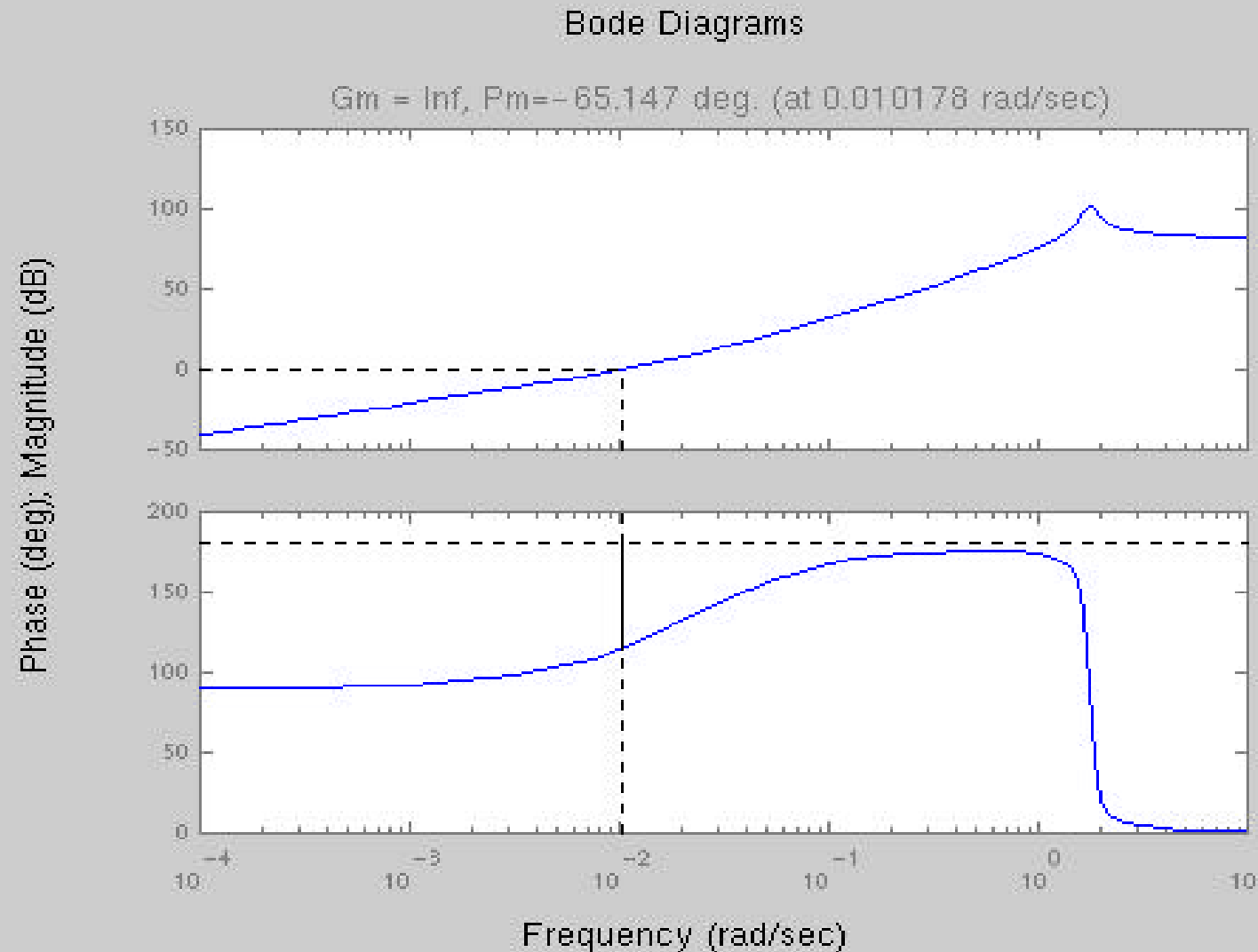
1DOF Translational Acceleration Design & Performance

- Design Requirement is the g-LIMIT Attenuation Performance Curve
- Proportional-plus-Integral-plus-Derivative (PID) type controller
- Pole placement technique utilized (with desired damping ratio of 70 % and a natural frequency of 0.0025 Hz)
- Matlab/Simulink used to facilitate design

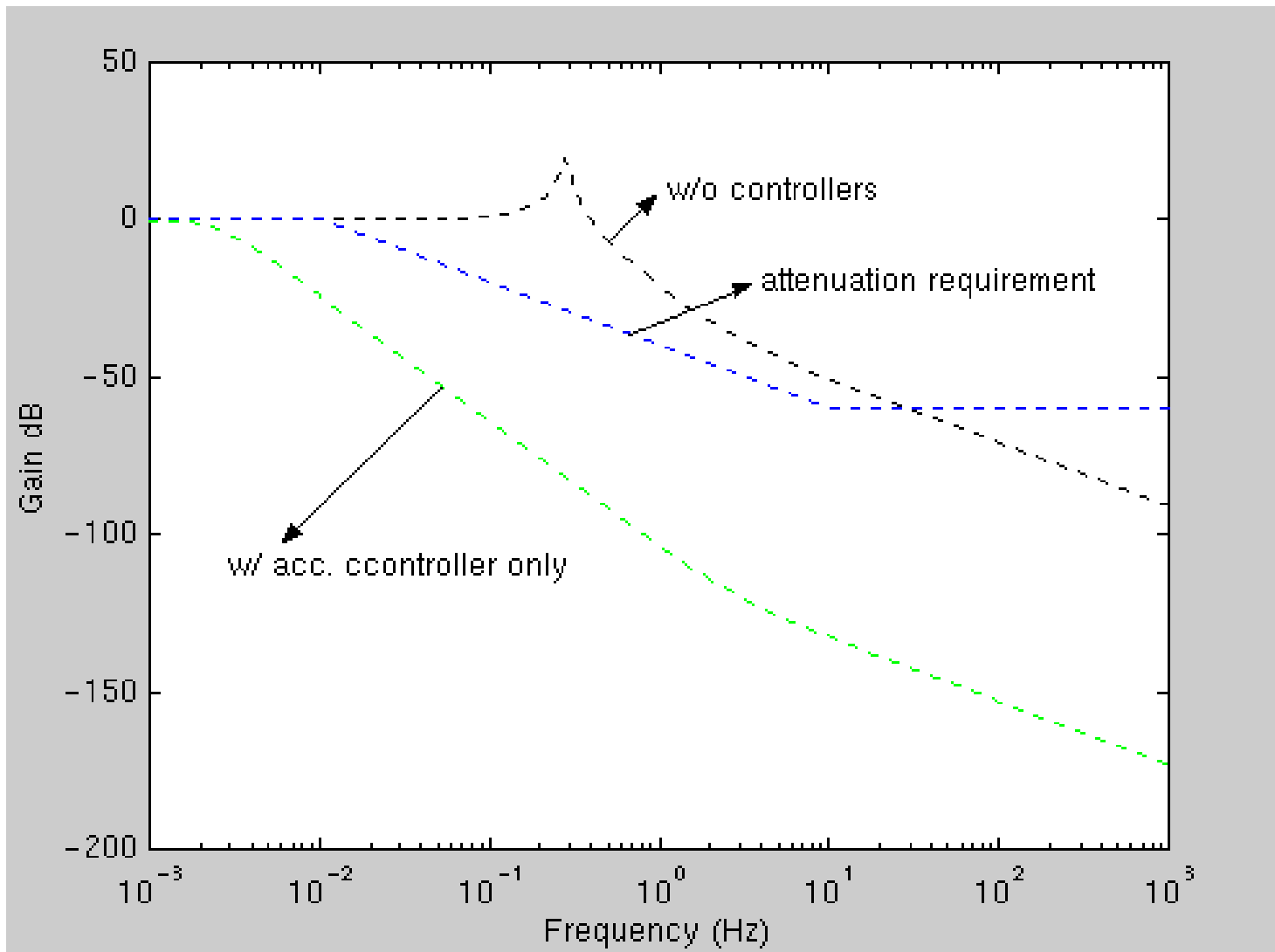
Root Locus for Translational Accel. Design



Stability Margins for 1-DOF Translational Accel. Design



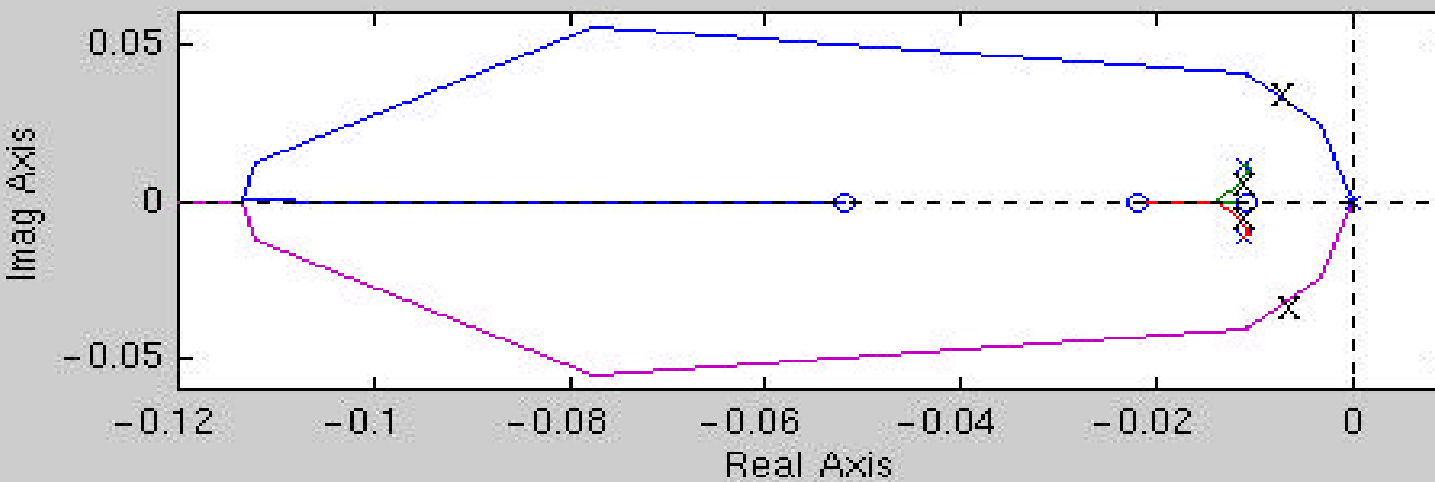
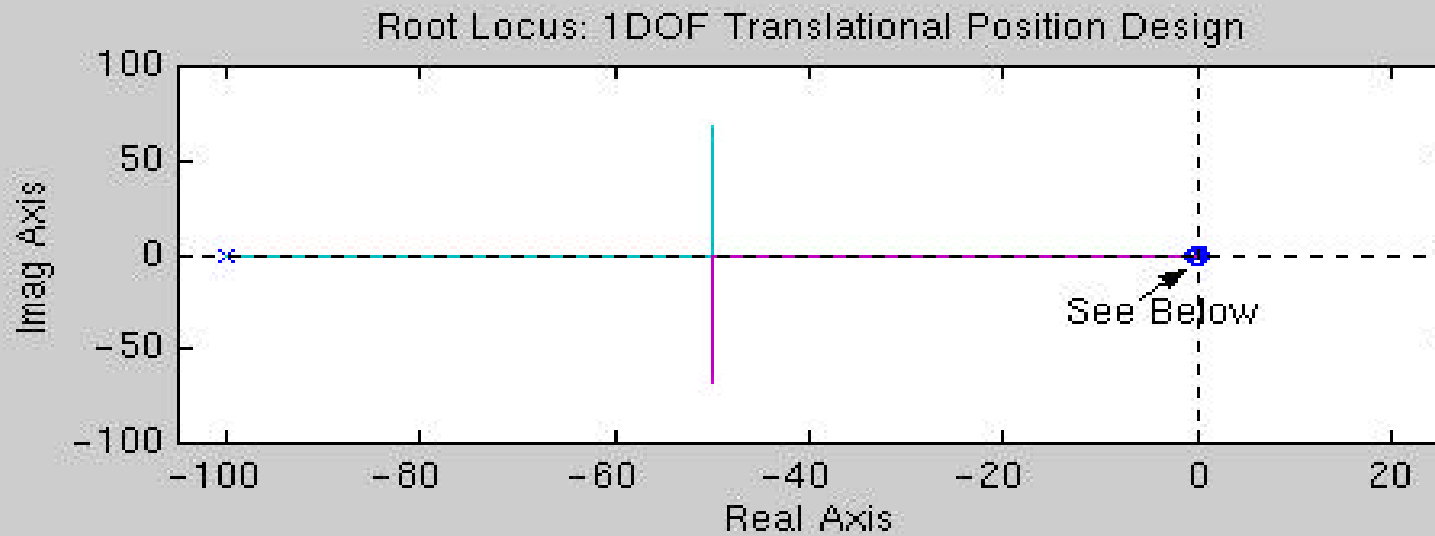
Baseline Acceleration Attenuation Performance (1 DOF; mass = 16.12 kg; stiffness = 50 N/m; 5% damping)



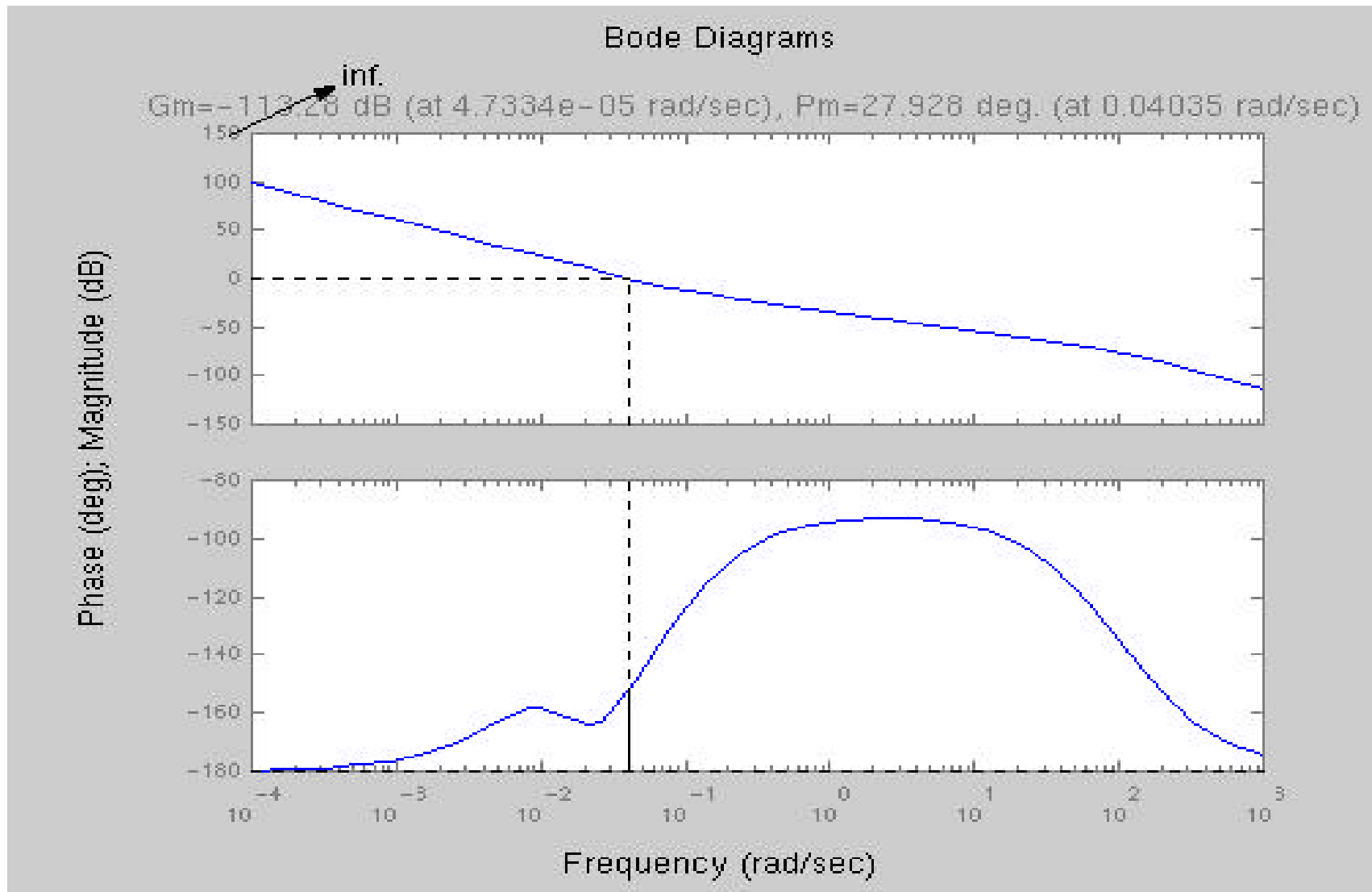
Translational Position Control

- Design requirement is to prevent the platform from hitting the stops (maintain platform close to center of the rattle space)
- Design goal: Slow (rise time of 30-50 secs) and stable response
- Proportional-plus-Integral-plus-Derivative (PID) type controller design
- Pole placement technique utilized to design PID gains
- Matlab/Simulink used to facilitate design

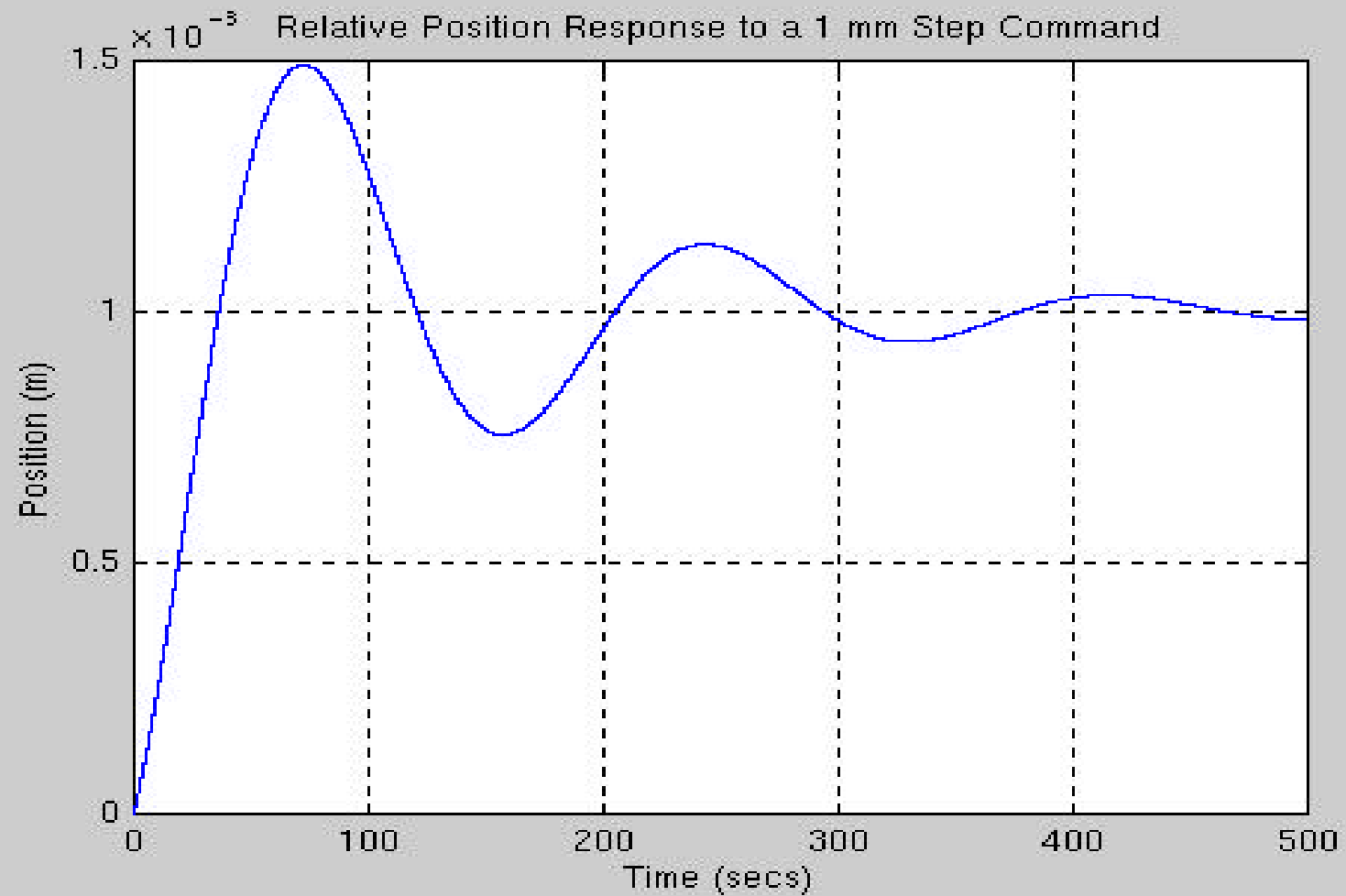
Root Locus for Translational Position Design



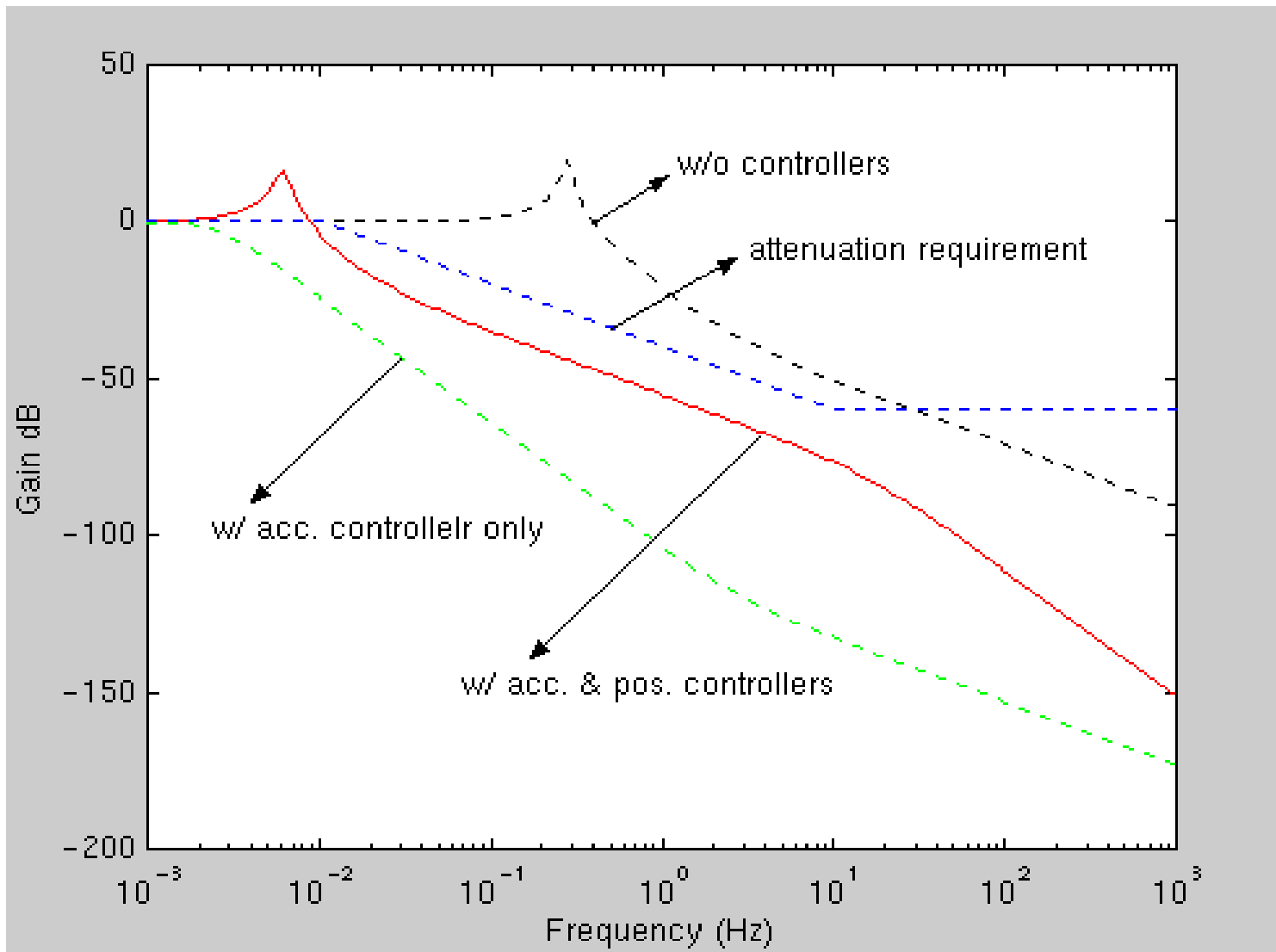
Stability Margins for 1-DOF Translational Position Design



Closed-loop Time Response



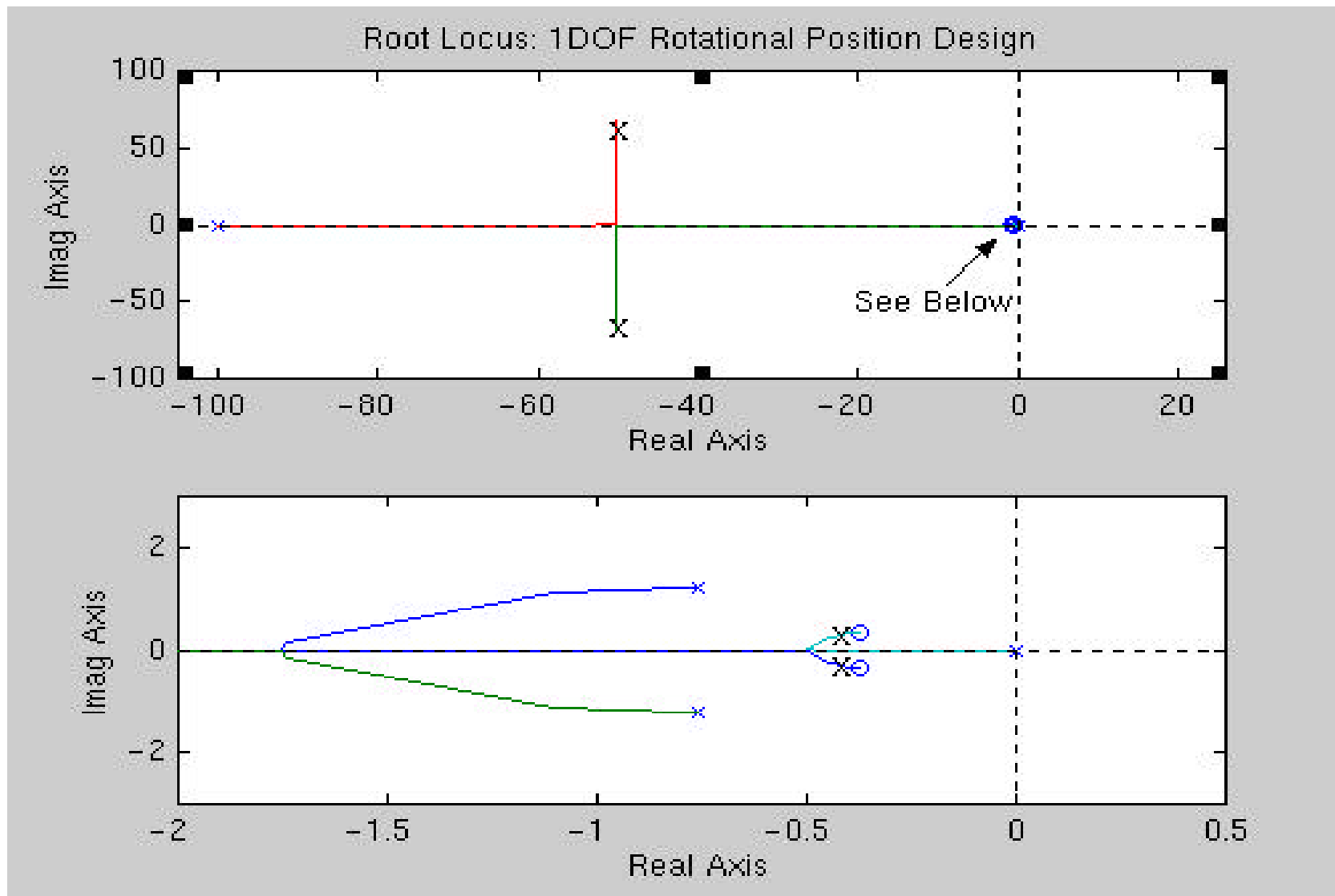
Baseline Acceleration Attenuation Performance (1 DOF; mass = 16.12 kg; stiffness = 50 N/m; 5% damping)



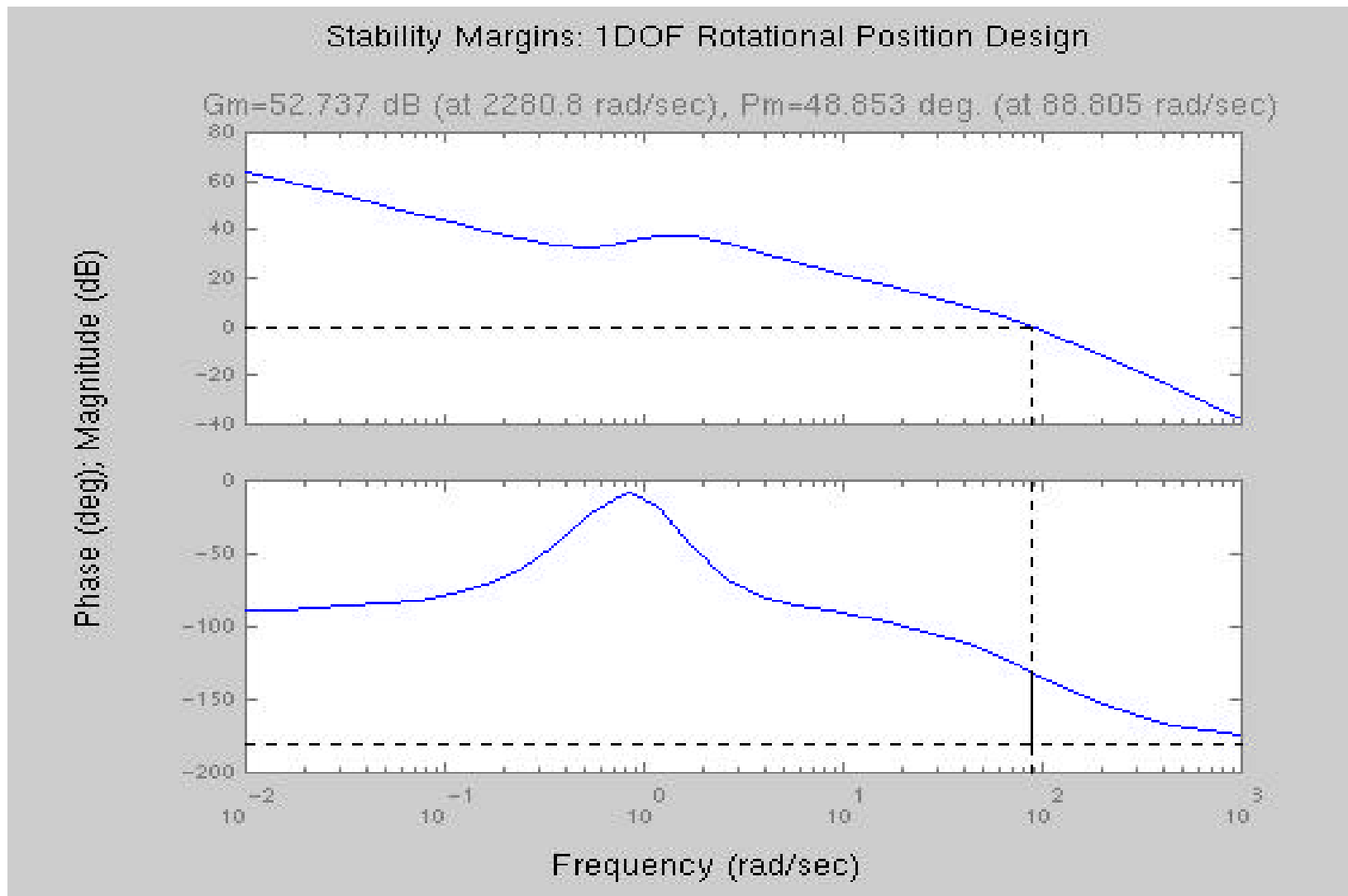
Rotational Position Control

- Design requirement is to prevent the platform from hitting the stops (maintain platform close to center of the rattle space)
- Fast/well behaved response (e.g., 70% damping with natural frequency of .5 rad/sec)
- Proportional-plus-Integral-plus-Derivative (PID) type controller design
- Pole placement technique used to design PID gains
- Matlab/Simulink used to facilitate design

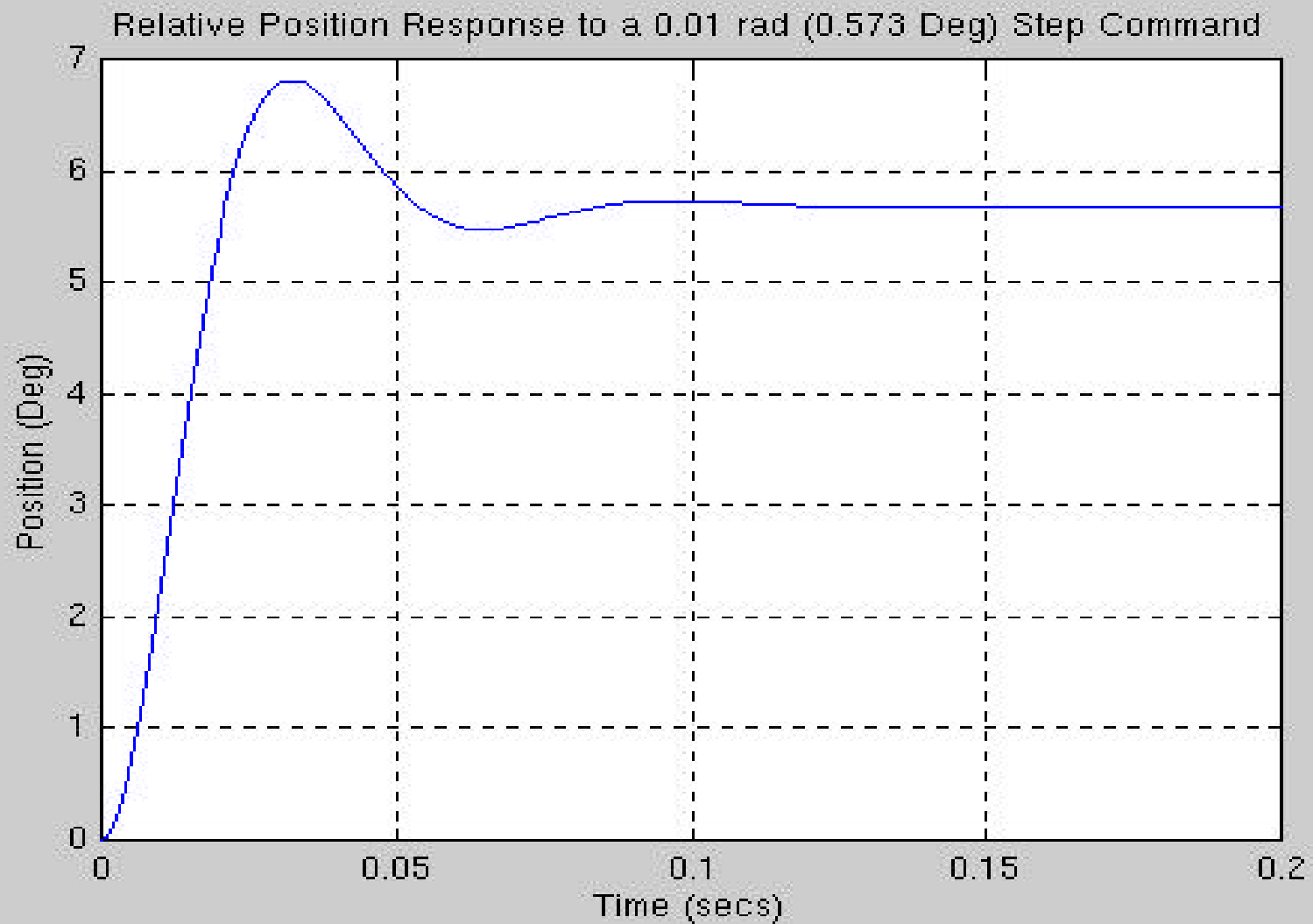
Root Locus for Rotational Position Design



Stability Margins for 1-DOF Rotational Position Design

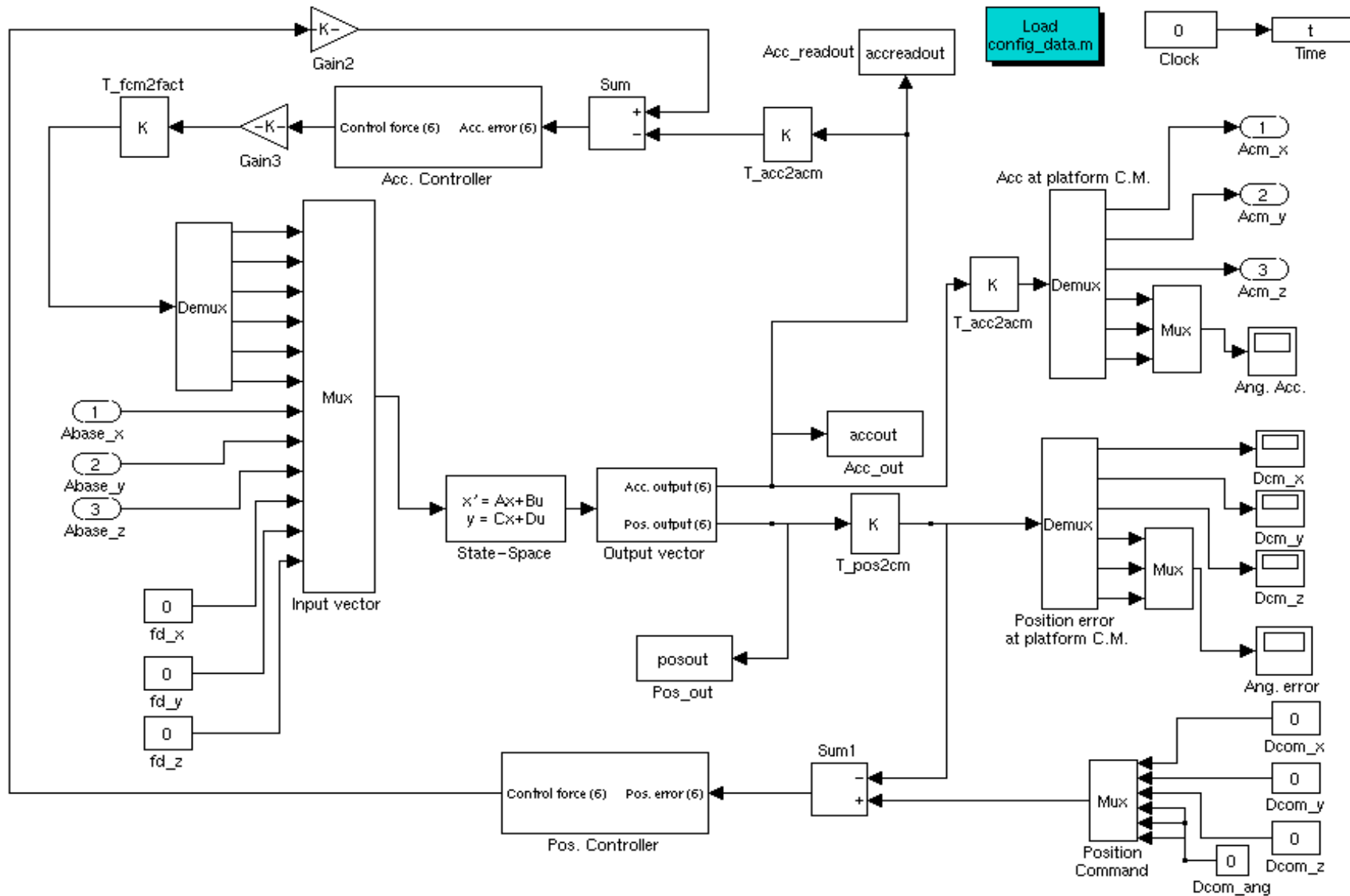


Closed-loop Time Response

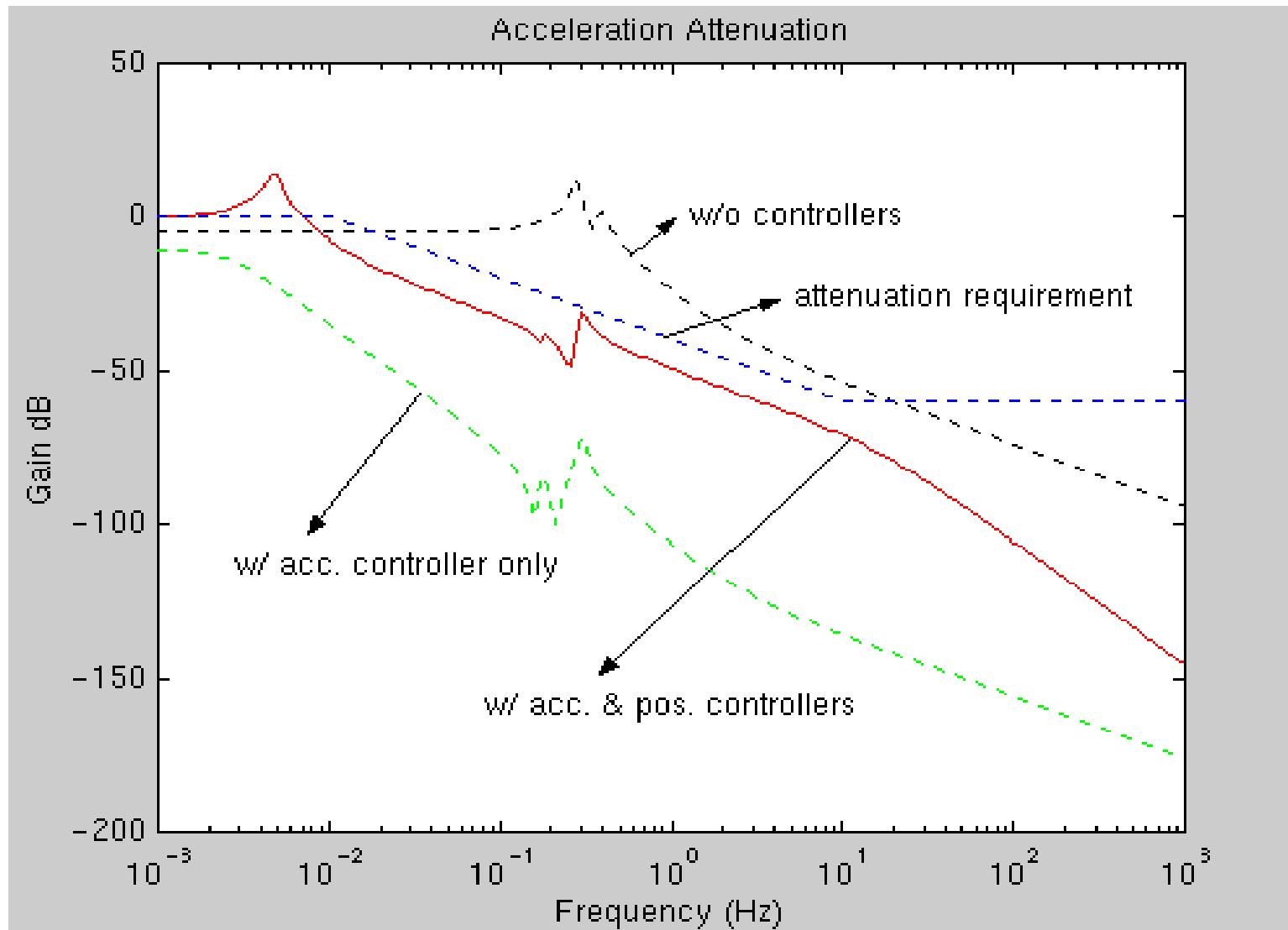


6-DOF performance analysis

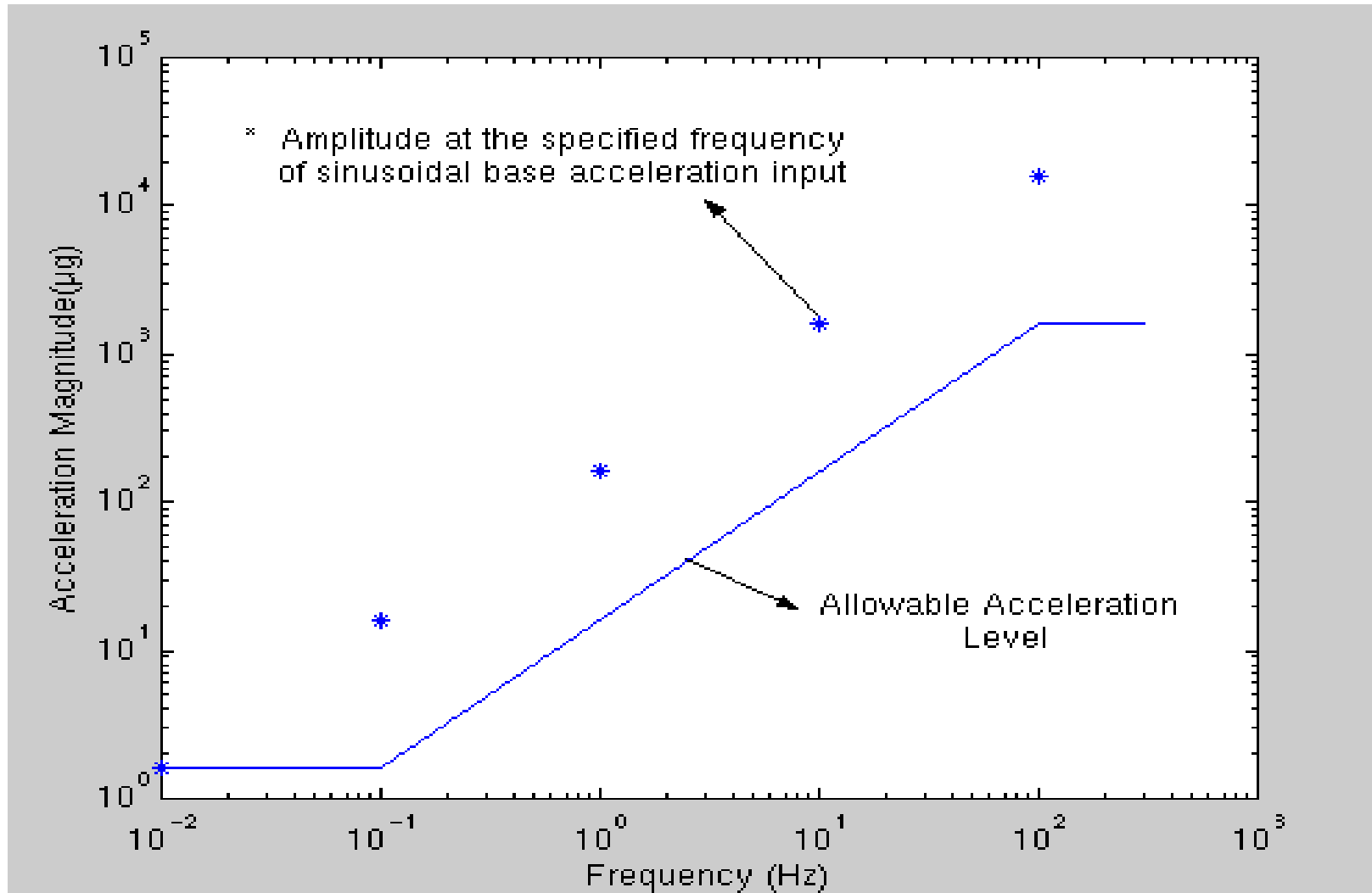
g-LIMIT 6 DOF Control Block Diagram



Baseline Acceleration Attenuation Performance (6 DOF model; x-component; w/ stiffness coupling)

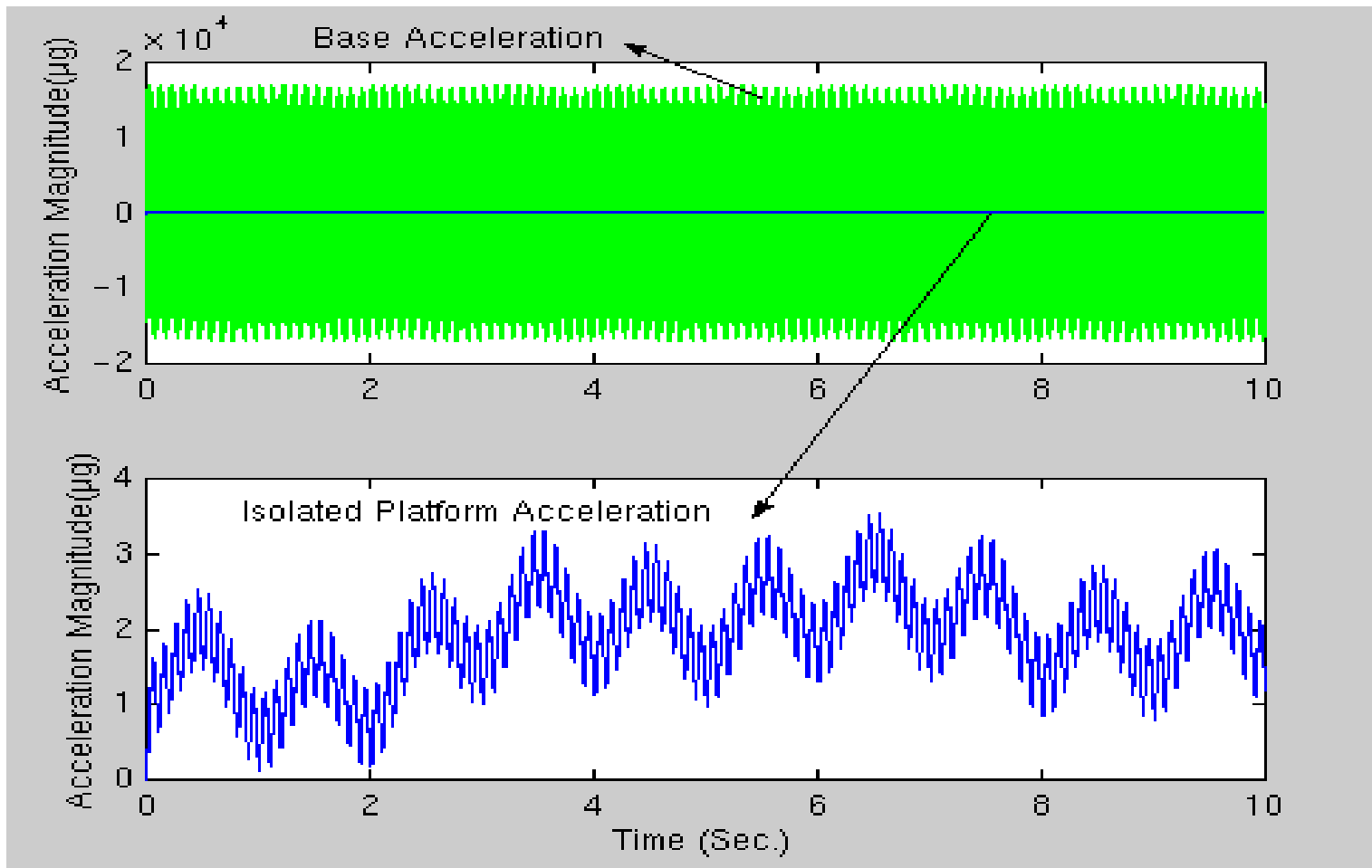


Acceleration Requirement and Base Acceleration Input for Transient Response Analysis

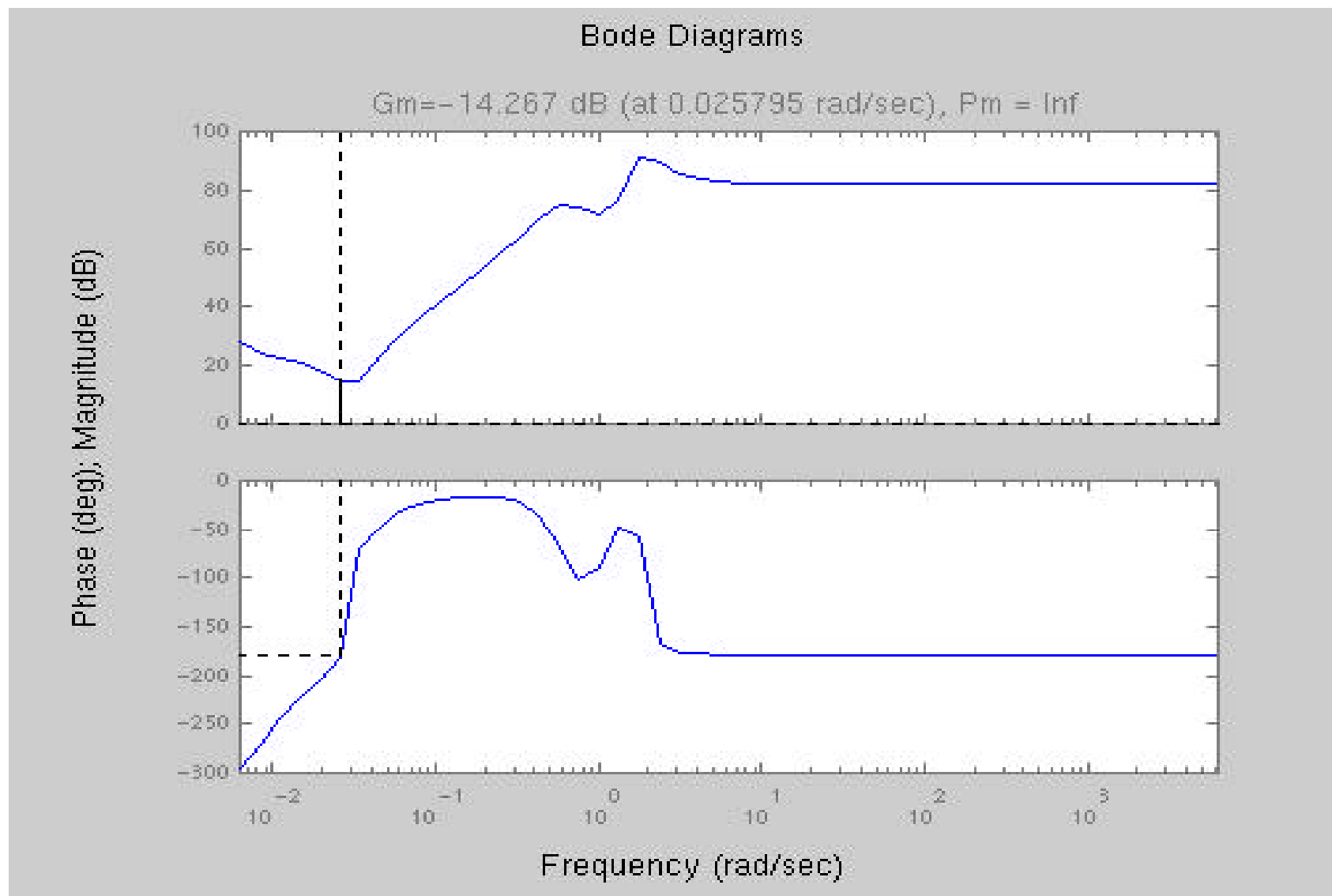


Transient Acceleration Response (unit: μg)

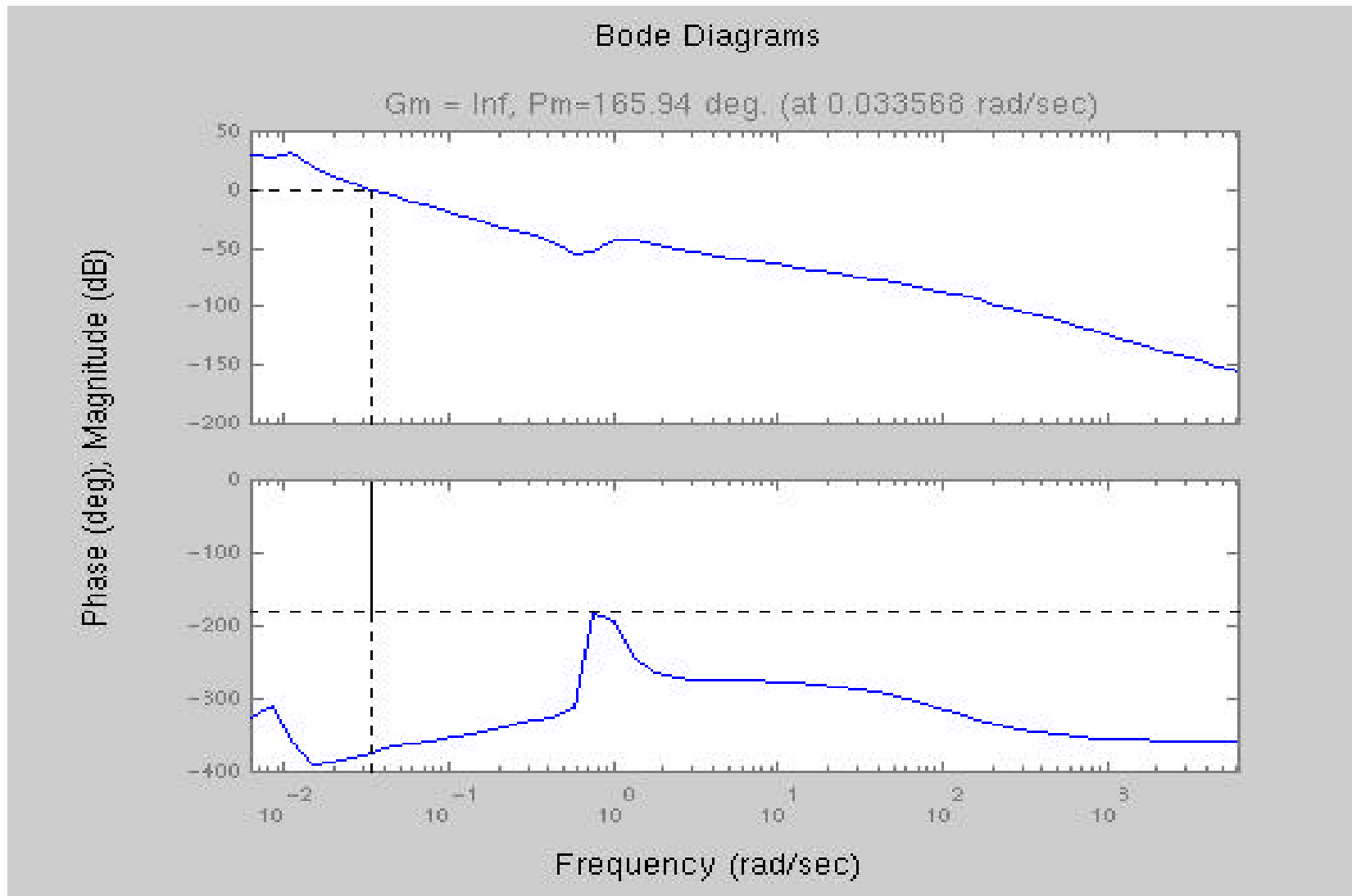
[Base acceleration = $1.6 \sin(0.01 \text{ Hz} \cdot t) + 16 \sin(0.1 \text{ Hz} \cdot t) + 160 \sin(1 \text{ Hz} \cdot t) + 1600 \sin(10 \text{ Hz} \cdot t) + 16000 \sin(100 \text{ Hz} \cdot t)$]



Stability Margins for 6-DOF Open-at Trans. Accel. Cmd



Stability Margins for 6-DOF Open-at Trans. Pos. Cmd



Summary

- Control system performance satisfies g-LIMIT requirements
- Stability margins are adequate
- Design approach results in a good baseline Central Single-Input-Single-Output (SISO) control law design

Future Work

- Optimize integrated performance of position and acceleration loops
- Incorporate sampling and filter effects
- Implement digital form of the control algorithms
- Include parameter variations and nonlinear effects
- Design anti-bump algorithm